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Scientific Letter

Neutralization of Home Made Explosives (HME) Hazards

Project Synopsis and Plan

Purpose

The purpose of this Scientific Letter is to deliver information on 02DA02.11 (ManADO 02.11) to the project leadership. This report contains a brief synopsis of the state of the research, a project plan (Annex A), and a draft framework for the main deliverable, the Explosive Ordnance Disposal (EOD) Field Reference Tool (Annex B). This report provides an updated list of deliverables and scheduling to account for the addition of US Technical Support Working Group (TSWG) funding and support through the signed Task Plan EX-4083-7 [1].

Background

Disruptors are tools used by EOD operators to neutralize explosive devices, which can contain a range of military, commercial, and improvised or Home Made Explosives (HME). The objective of a disruptor is to interrupt the firing chain of an Improvised Explosive Device (IED) and disperse its contents to preclude detonation and allow for inspection and evidence collection. The disruptor projectile (e.g., water jet, steel slug, gel, etc.) has to be sufficiently powerful to penetrate the case of the IED and disconnect or destroy the firing chain components in less time than a detonator requires to function (i.e., the committal time).

Since the contents of an IED are often not known, the projectile is usually directed through the largest dimension of the case. As a result, it may end up going through the main explosive charge at some point in the disruption. While most military explosives, such as TNT and C4, are relatively insensitive and are simply scattered by the projectile, some HME mixtures are much more sensitive to shock and friction than conventional explosives, and may be detonated by a high-velocity projectile.

Choosing the right disruptor therefore becomes a balance between having enough power to penetrate and disrupt the IED, but not too much power so as to set off the charge. In order to make this choice, the operator needs information about how various explosives react to different disruptor systems. What is required is an EOD HME field reference (likely in the form of a series of charts or a field manual) that will inform what disruptor system should be used against an IED containing a certain type of explosive. This will take into account the sensitivity of the explosives and the characteristics of the disruptor projectile.

Justification

Joint Counter Explosive Threat Task Force (JCET TF) previously identified their priority S&T requirements [2], which included a specific request to address "neutralization of HME" in support of Improvised Explosive Device Defeat (IEDD). Information about the sensitivity of explosives to disruptors and their projectiles is essential to the Canadian Armed Forces (CAF) and public security organizations. EOD staff officers, instructors and operators require this information, as it will help in doctrine formulation, training, and will inform on the decision of which disruptor system to use against a particular threat. A lack of information could pose a danger to the EOD operator and/or the public through unintended detonation of the threat, unintentional destruction of evidence, and/or collateral damage to CAF and public assets.

Exploration of HME initiation also presents opportunities to further the science behind unconventional explosive initiation and characterization techniques. A number of novel HME mixtures are being found in theater, and should be tested for sensitivity to projectiles.

Mission Statement

This project aims to provide the CAF with information about neutralizing HME threats in the form of an EOD field reference tool.

Current and Existing Work

DRDC - Suffield Research Centre has conducted several related activities on this topic (e.g., [3-6]). Characterization and sensitivity tests have been conducted on several HME formulations, which provide a basis for ManADO 02.11 to build on. Scoping tests were completed in 2008 and 2009 in order to determine the susceptibility of several disruptors to detonating conventional explosives. In-service CAF disruptors (e.g., Spike, Minimod, and Pigstick) were tested against Powerfrac Dynamite, TNT, ANFO, and C4 charges. In August 2010, work began under Chemical, Biological Radiological and Nuclear Research and Technology Initiative (CRTI) (PC206-0204RD) using the Minimod, Stingray, Spike, and Pigstick to collect water jet velocity data and sensitivity against 10 different HME mixes (a matrix that is considered to be a general representative of the current disruptor/threat environment). This work was continued under a Master of Science (MSc) thesis study [6] within DRDC - Suffield Research Centre. This thesis project expanded on previous experimental trials by including more in-depth analysis of water jets, and the interaction between water jets and three HME mixtures. More recently, under ManADO 02.11, the original trial matrix set forth in 2010 was completed. Data from this series was used to create a draft framework for the EOD Field Reference (Annex B). Additionally, a contracted literature review of current and past modelling efforts in HME response to water jets, along with a road map of potential future modelling activities, is expected by the end of FY 14/15. These activities form the basis for the upcoming activities under this 02.11 project.

The initial work conducted at Suffield under previous projects, provides the baseline data required to develop a framework for the EOD field reference tool and is the basis for 02.11. The next phase of 02.11, augmented with funding from TSWG [1], will fill in the framework of the HME field reference tool and expand on the baseline data by: 1) filling gaps in the data, 2) investigating the potential for a predictive model, and 3) providing the field reference as electronic media.

Other methods of HME neutralization exist (e.g., chemical [7]), however this project focuses on disruptor technologies, and does not explicitly explore other technologies in-depth. More importantly, leverage for other topics and areas of interest could be exercised through information exchange from this project that would augment this projects contribution. In particular DRDC – Valcartier Research Centre is currently in the experimentation phase of a project to determine the effect and use of High Energy Lasers (HEL) against HMEs [8]. This HEL project is scheduled to receive funding from 02.11 (with TSWG funds) and results and analysis from this project would augment the water jet based research from 02.11.

Allied Nations have also conducted research in this area. Australia, UK, and Singapore are currently interested in HME neutralization, and the modelling of HME response to neutralization tools. All have expressed interest in obtaining access to the data and analysis from this project.

Objectives and Deliverables

The central goal of this project is to develop a HME neutralization field reference for use by EOD operators. This project proposes three phases of research to provide the CAF with information about the reaction of various HME threats to various disruptor systems.

With the additional TSWG funding, the project will be able to leverage larger efforts in the European Union (and others, mechanisms yet to be determined) in the area of HME neutralization (see Figure 1) that will further add to the depth of the information and capability of the tool.

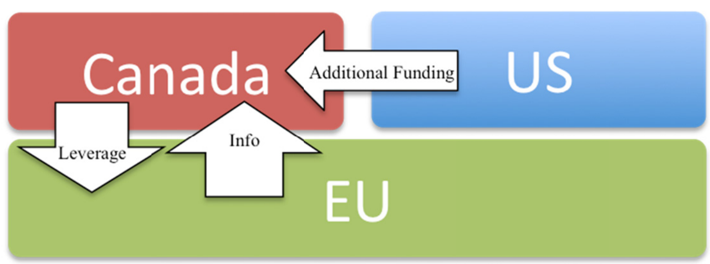

Figure 1: *Leverage of International Efforts on HME Neutralization.*

The objectives of the project are:

1. Develop and expand an EOD HME field reference tool capability within the constraints of the project timeline;
2. Exchange information with partners that is relevant to the disruption of improvised explosives;
3. Investigate the potential for development of a predictive HME initiation model, and develop if possible within the constraints of the project timeline;
4. Create an electronic version (mobile application / e-book / searchable media) for use by the EOD community within the constraints of the project timeline; and
5. Expand the knowledge of HME neutralization for the broader allied research community.

High Level Project Plan

A high-level overview of the project flow is represented in Figure 2, with more details provided in Annex A. The project has four phases (plan, experiment, analyse, and report) and two main

activities: the development of the Field Reference Tool, and the development of a Predictive Modelling Capability. Iterations between analysis and planning will occur for both activities, and experimental data from field trials will be used to validate the modelling efforts.

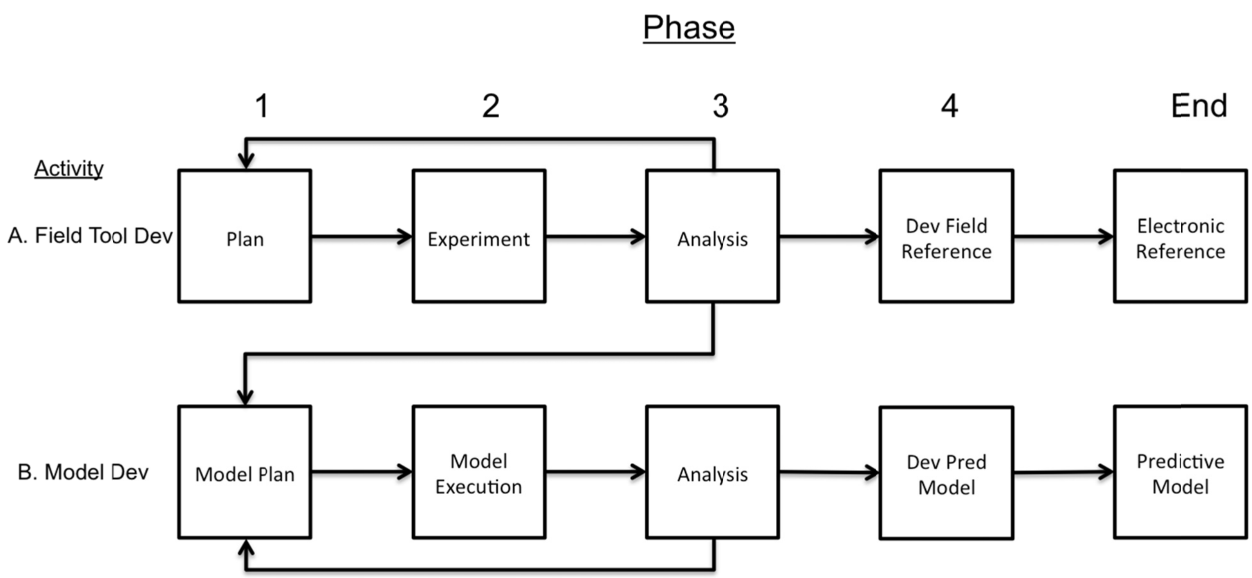

Figure 2: *Project Flow Chart.*

The critical path for this project is the EOD Field Reference Tool activity (Activity A–Field Tool Dev in Figure 2), with a projected end in FY 17/18. Focus will be applied to this activity to ensure delivery of the main objective (Field Reference Tool), while exploration of the modelling aspects of the project will continue while viable.

Funding Plan

The funding plan for upcoming fiscal years is provided in Table 1. The funding level from TSWG is $600K, and was made available FY 14/15.

Table 1: *Funding Plan.*

	Funding for Year and Source					
	FY 15/16		FY 16/17		FY 17/18	
	ManADO 02.11	TSWG	ManADO 02.11	TSWG	ManADO 02.11	TSWG
Minor Procurement	$17K	$0	$20K		$20K	
Contracting	$35K	$150K	$35K	$100K	$35K	$50K
TD	$8 K	$0	$5K	$5K	$5K	$5K
DRDC Pers (Student)	$0	$60K	$0	$60K	$0	$60K
Supp. to DRDC Val	$0	$50K	$0	$50K	$0	
Total	**$60K**	**$260K**	**$60K**	**$215K**	**$60K**	**$115K**

Conclusion

This Scientific Letter report provides a brief summary of previous work in the area of HME neutralization, a high-level project plan with projected funding levels, and a summary of the way forward, with the impact from increased funding levels, in achieving the development of an EOD Field Reference Tool for the CAF EOD community in general. More details on the way forward are provided in both Annex A – Project Plan and Annex B – Explosive Ordnance Disposal (EOD) Field Reference Tool Framework.

Ultimately, the project advanced research plan (delivery September 2015) will require buy-in and support from JCET TF and TSWG.

Prepared by: Matthew WJ Ceh (DRDC – Suffield Research Centre).

References

[1] Department of Defence, "Disrupter Neutralization of HME Threats - Task Plan EX-4083-7," Department of Defence, ed., 2014.

[2] L. P. Peril, DComd CF CIED TF, "Identifying and Filling CIED/EOD Capability Gaps and to Meet the Evolving Enduring Threat," 27 March 2013.

[3] M. Ceh and M. Dunning, "The Test & Evaluation of IED Disrupter Equipment: Large Targets," DRDC – Suffield TR-2010-288, 2010.

[4] M. Ceh, M. Dunning, C. Pollock, and T. Macleod, "The Test & Evaluation of IED Disrupter Equipment: Small Targets," DRDC – Suffield TR-2011-120, 2011.

[5] T. Josey, "Long Range Capability of Disruptors - Preliminary Investigation," DRDC – Suffield TR 2012-155, 2012.

[6] P. K. Lambert, "The Sensitivity Of Selected Homemade Explosives (HMEs) To Water-Jet Disruption Techniques," Department of Mechanical Engineering, New Mexico Institute of Mining and Technology, Soccoro, NM, 2013.

[7] Technical Support Working Group, "Desensitization of Homemade Explosives - Technical Reference," Combating Terrorism Technical Support Office 2014.

[8] D. Pudo, "HIGH ENERGY LAND LASER OPERATION (HELLO) II TRIAL - Target plan," Defence R&D Canada, DRDC – Valcartier, 22 October 2014. (In-progress).

Attachments

Annex A: Research Plan

Annex B: Explosive Ordnance Disposal (EOD) Field Reference Tool Framework

This Scientific Letter is a publication of Defence Research and Development Canada. The reported results, their interpretation, and any opinions expressed therein, remain those of the authors and do not necessarily represent, or otherwise reflect, any official opinion or position of the Canadian Armed Forces (CAF), Department of National Defence (DND), or the Government of Canada.

Annex A Research Plan

This research plan has two main themes, the development of a field reference tool, and a predictive model tool. The main effort in this project will focus on the former, since the modelling effort currently has uncertain value, and is waiting for delivery of a scoping report from the modelling contractor (expected delivery end FY 14/15, and published by end June 2015), which will assess the plausibility of a predictive model.

Phase 1

Field Reference Tool Development

The objective of the first phase of this project is to develop a research plan for the development of the EOD HME Field Reference Tool. Methods and test procedures will need to be reviewed and assessed, and gaps in existing research will need to be addressed. The following activities will be conducted under the first phase of the project:

1. An appropriate HME threat and neutralization tool matrix must first be defined (i.e., re-evaluate the previous matrix to bring it up to date with recent information);
2. Literature reviews along with field experiments will be conducted to explore and validate the methodologies and experimental setups that will determine:
    a) The reaction of various HME/projectile velocity combinations;
    b) The projectile velocity of a variety of disruptors used by the CAF and public security organizations;
    c) The energy delivered to a target at a variety of distances (e.g., for different stand-off distances);
    d) The energy/velocity/impulse threshold for detonation of a variety of explosives; and
    e) The sensitivity of various HME mixes to shock, friction, and temperature.
3. Exploring additional disruptor systems and HME mixes; and
4. Exploring the effects of stand-off, barriers, and other factors on the reactions of HME.

The main deliverables of this phase of the project are:

Item	Description	Date
Synopsis Report	Draft a synopsis on the current state of the research that will: a) Highlight gaps in the current study, b) Propose measures to address future trends in HME and Improvised Explosive Device Defeat (IEDD) tool development.	June 30, 2015
Advanced Research Plan	Develop an advanced research plan for a more comprehensive EOD HME Field Reference Tool Chart.	September 30, 2015

Predictive Model Tool Development

The following activities will be conducted under the modelling aspect of the project:

1. Validating the concept of a predictive model (i.e., what are the limitations and sensitive variables?); and

2. Exploring different techniques for numerical modelling of the interaction of HME mixes and disruptor projectiles. Modelling will help to validate experimental results and provide a means to create a predictive capability within the field reference.

The main deliverables of this phase of the project are:

Item	Description	Date
Contract Modelling Report	Contractor report on the state of modelling of HME, disruptors, and the interaction of the two.	June 30, 2015
Modelling Research Plan	Develop a research plan for modelling of HME response to water jets.	June 30, 2015

Phase 2

The second phase of the project will action the research plan developed in the first phase, and further develop the framework for the EOD HME field reference. The level and type of modelling efforts will be based on the modelling research plan developed in the previous phase.

Field Reference Tool Development

Example possible activities under this phase are:

1. Supplementing information on other HME mixes not included in the initial phase;
2. Supplementing information on the effect of various standoff distances, to account for different Standard Operating Procedure (SOP) (from different disruptor manufacturers) as situations dictate; and
3. Investigating the effects of barriers on the sensitivity results for the various HME mixes through field trials.

Predictive Model Tool Development

The following possible activities may be conducted under the modelling aspect of the project, depending on the plan in development:

1. Numerical modelling of the interaction of HME mixes and disruptor projectiles; and
2. Investigating/developing a framework for a predictive initiation model that could be used as a more comprehensive EOD tool that will provide an enduring capability for the CAF.

The main deliverables of this phase of the project are:

Item	Description	Date
Status Report	A status report that summarizes the completed research, and describes the EOD HME field reference framework.	March 31, 2016

Phase 3

The third phase of this project will compile the collected data and combine it with the developed framework to produce the EOD HME field reference.

Field Reference Tool Development

Activities under this phase are:

1. Combine and synthesize data into the field reference tool;
2. Assess any gaps in the research and present a plan to address them, or exit the phase and complete the field reference tool with the available data; and
3. Develop a plan to make an electronic version of the field reference (e.g., e-book, mobile application, etc.).

Predictive Model Tool Development

Activities under this phase are:

1. Validate the model with experimental field trials;
2. Improve the model if possible;
3. Determine what the gaps are and present solutions; and
4. Determine if further effort in modelling is viable with the available resources.

The main deliverable of this phase of the project will be a report that summarizes the completed research, and describes the progress made in developing the EOD HME field reference. This is the “off ramp” point for modelling efforts if there is no value in continuing.

Item	Description	Date
Status Report	A status report that summarizes the completed research, and present any issues in the development of the EOD HME field reference tool. Status of the modelling efforts are discussed, with a “go/no go” for ongoing effort.	December 31, 2016

Phase 4

This phase of the project is the electronic tool development phase and reporting phase. The final version of the Field Reference Tool is presented in paper form and electronic form.

The main deliverables for this phase are:

Item	Description	Date
EOD HME Field Reference Tool Chart	A report that presents the non-electronic version of the EOD HME field reference tool.	March 30, 2017
Final Report	A report that summarizes the completed research, and presents the electronic EOD HME field reference tool. A plan is presented to incorporate the modelling efforts if deemed relevant.	July 31, 2017

Timeline

The proposed timeline for the four phases is provided in the Gantt chart below.

Table A.1: *Gantt Chart for Neutralization of HME Hazards.*

		Apr-14	Apr -15	Apr -16	Apr -17
Field Reference Dev.	Plan	Phase 1			
	Experiment		Phase 2		
	Analysis			Phase 3	
	Reporting			Phase 4	
Predictive Model Dev.	Lit Rev./Plan	Phase 1			
	Model Exec.		Phase 2		
	Analysis		Phase 3		
	Reporting			Phase 4	

Work Effort for FY 2015/16

This FY will encompass two phases of the project, planning and experimentation. It will require an estimate of four to six weeks of trials involving the test of IEDD equipment against various HME mixes, and characterization of IEDD tools and HME sensitivity (not including trial preparation and clean up). Effort will also be required to complete data reduction and analysis, and reporting.

Effort in the modelling of HME reactions will be required, with most of this effort contracted. Field trials will be used to support validation and development of the modelling framework.

Resources Required

The funding will be divided up into minor procurement, travel, contracting, support to other lab efforts, and hired support (students). Details are provided below.

Minor Procurement

Trial supplies. Purchase and replenishment of DRDC – Suffield supplies of disruptor equipment and consumables. Estimated expenditure: $17K.

Travel

Travel to meet with the end user (Counter Improvised Explosive Device Task Force (CIED TF), Director Land Requirements (DLR-7), EOD, TSWG) about the requirements and deliverables of the project, exchange information on SOP, and gain end user buy-in. Travel to the US to promote and exchange ideas about the project with US counterparts. Estimated expenditure: $8K.

Contracts

Contracted services from third-party assistance in trial support and data reduction and analysis are required. Estimated expenditure: $35K.

Contracted services from third-party assistance in modelling support and data reduction and analysis are required. Estimated expenditure: $150K.

Project Support

Support will be provided to DRDC – Valcartier Research Centre from TSWG funds for the HEL project. Estimated expenditure: $50K.

Hired Support

Support will be required from a third-year 16-month internship Mechanical Engineering student. Estimated expenditure: $60K.

Annex B Draft Explosive Ordnance Disposal (EOD) Field Reference Tool Framework

This section presents the draft framework for the EOD Field Reference Tool. Figure B.1 provides a graphical representation of the framework at the time of publication on this report.

The y-axis lists the HME mixtures tested, while the x-axis is the velocity of the water jets from tested disruptors. Vertical dotted red lines indicate the disruptor system that corresponds to the velocity in the x-axis. The figure excludes the mixture type, velocities, and disruptor names since it is deemed sensitive data. Labels are used, with generic names to represent the disruptors used.

A colour scheme is used to represent the reaction of the HME mixes to the corresponding disruptors. Green represents no reaction, with a resulting dispersal of the HME mixture. Yellow represents an observed reaction, such as a deflagration or low-grade exothermic reaction. Red represents a high-order detonation of the mixture. Hashed lines represent a transition area between the reaction zones (i.e., green to yellow, yellow to red, and green to red).

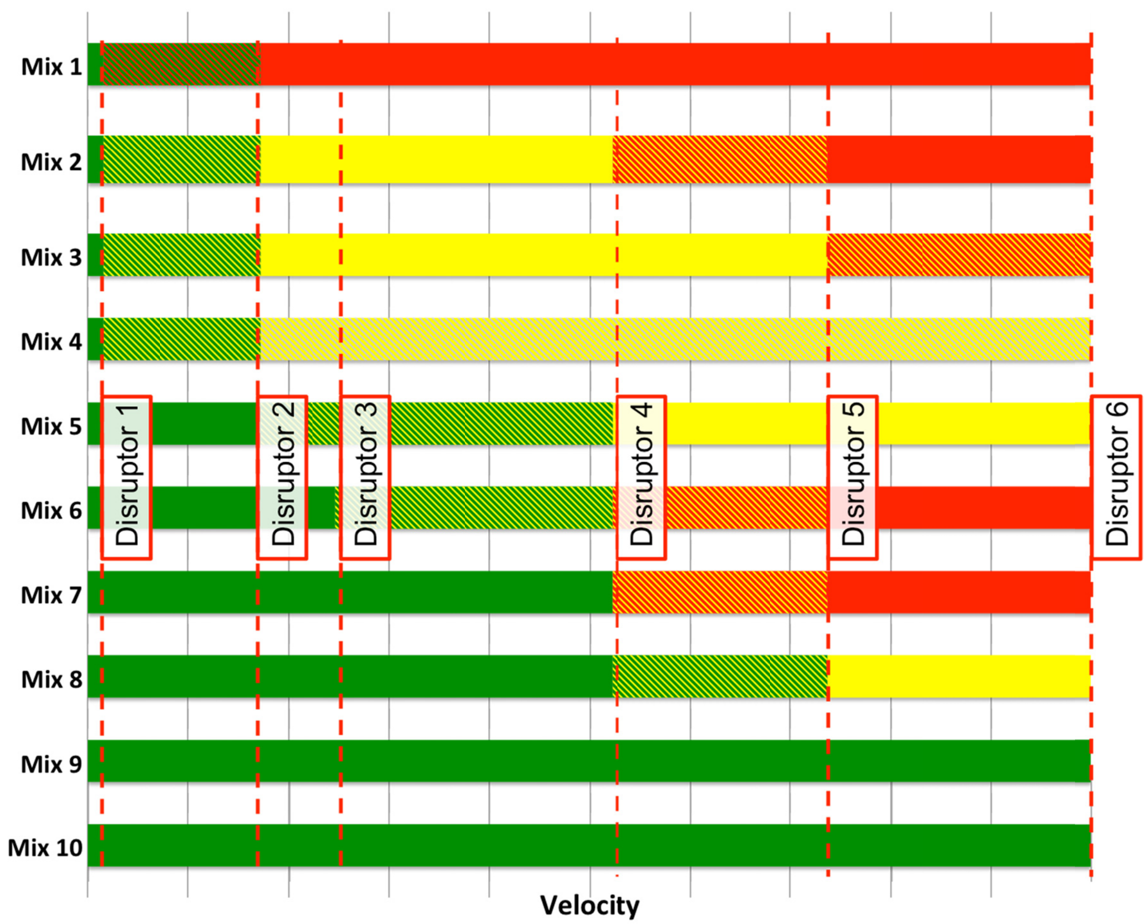

Figure B.1: *Draft Framework for the EOD Field Reference Tool.*

The HME mixtures tested are based on previous work completed under the CRTI project PC206-0204RD, and represent a cross section of mixtures observed in theatre. The disruptors chosen for testing are also based on previous work completed under the CRTI project PC206-0204RD, and represent low to high water jet velocities. Further study will be focused on refining the choice of the threat to tool matrix presented here. Further information on the actual tools and mixtures used can be obtained from the author.

Some general observations about Figure B.1 and the results are that:

1. The chosen mixtures represent a good combination of sensitive and insensitive HME formulations.
2. There are large areas of transition zones that will require further exploration (use a higher variety of water jet velocities).
3. The use of velocity as an indicator may not be fully representative of disruptor/HME interaction.
4. HME consistency (i.e., density, ratio, voids, particle size) likely plays a large role in the repeatability of experiments and sensitivity of HME to mechanical insult.

The observations presented above will be the basis for the more advanced experimental campaign that will be elaborated on in the next deliverable, the Advanced Research Plan due September 30, 2015.